Iowa DOT Linear Referencing Development Project

Iowa Department of Transportation

GeoAnalytics

TRANSDECISIONS

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Session Agenda

- Quick Overview
- Field Pilot Results
- LRS Data Model
- System Architecture & Technology
- Future Direction
- Questions

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Presenters

- Bill Schuman - Iowa Department of Transportation
- Tom Ries - GeoAnalytics, Inc.
- Julian Ray – TransDecisions, Inc.

- Many other valuable contributors to the project

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A Quick NCHRP 20-27 and Project Review

Bill Schuman

Iowa DOT

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A couple definitions...

- LRM - Linear Referencing Method
  - » Different methods of measuring linear locations; (i.e. milepost, stations, etc.)
- LRS - Linear Referencing System
  - » a set of procedures and methods for specifying a location as a distance, or offset, along a linear feature, from a point with known location

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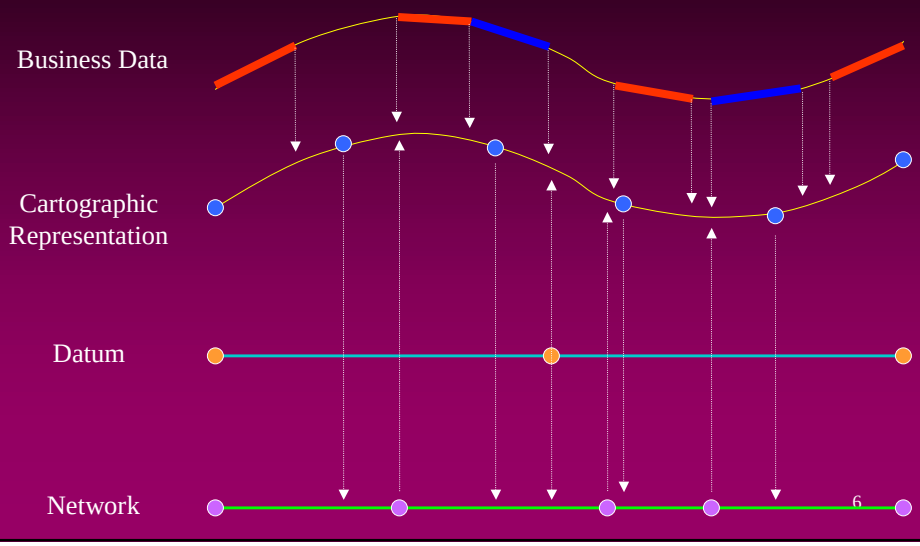
Linear Referencing

The problem we tried to solve...



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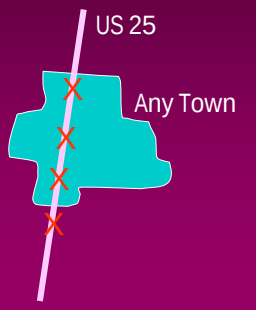
LRS Complexities

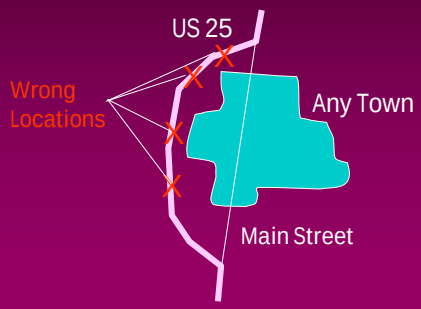
Route-based network links

By-pass example:

Before by-pass



After by-pass



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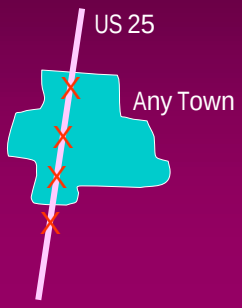
LRS Complexities

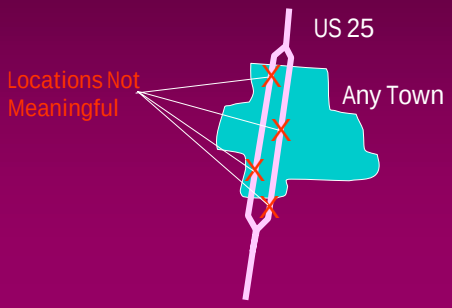
Route-based network links

Improved roadway example:

July 27, 1999



July 27, 2000



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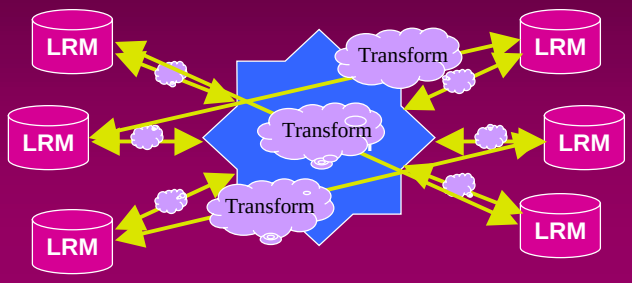
Linear Referencing

The problem we tried to solve...

A common linear description of the network that can relate all the methods.



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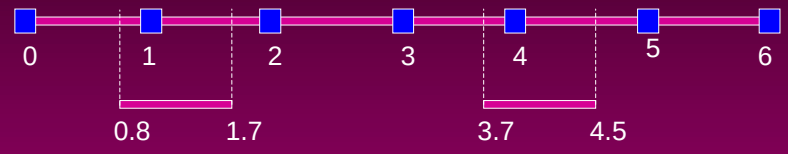
Linear Referencing Methods

Distance Measure

Route 0023



ROUTE_ID	BEGIN_DISTANCE	BEGIN_SECID	END_DISTANCE	END_SECID	ATTRIBUTES
0023	0.8		1.7		...
0023	3.7		4.5		...

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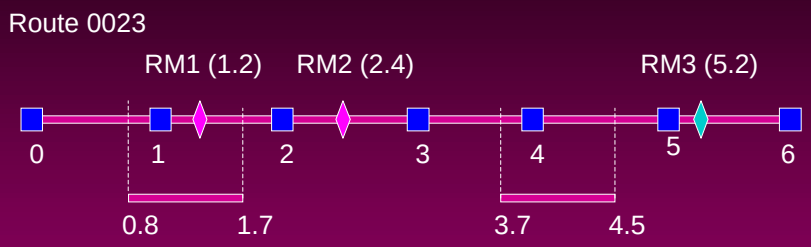
Linear Referencing Methods
Reference Marker Offsets



ROUTE_ID	BEGIN_MARKER	BEGIN_OFFSET	BEGIN_SECID	END MARKER	END_OFFSET	END_SECID	ATTRIBUTES
0023	RM1	-0.4		RM1	0.5		...
0023	RM2	1.3		RM3	-0.7		...

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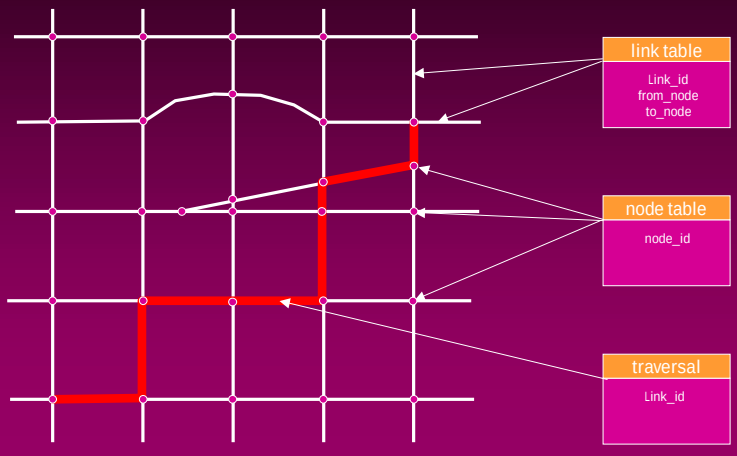
Network Modeling
Routes, traversals and path analysis



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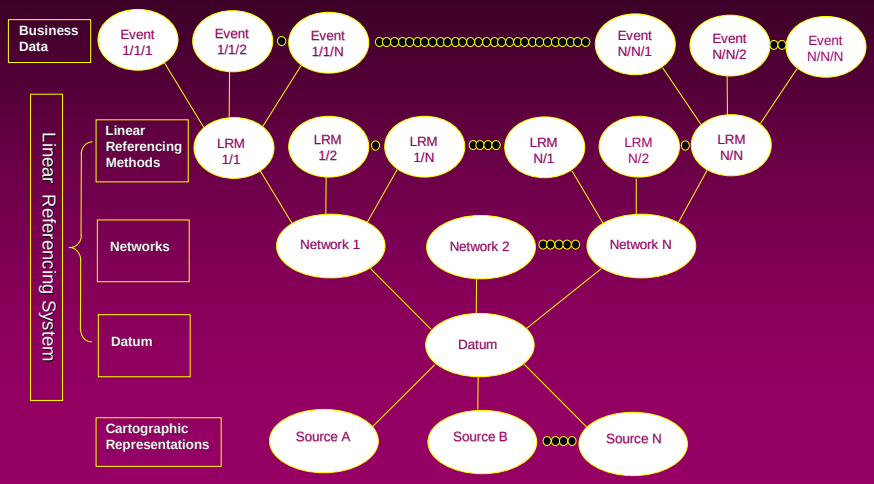
NCHRP 20-27 Conceptual Model



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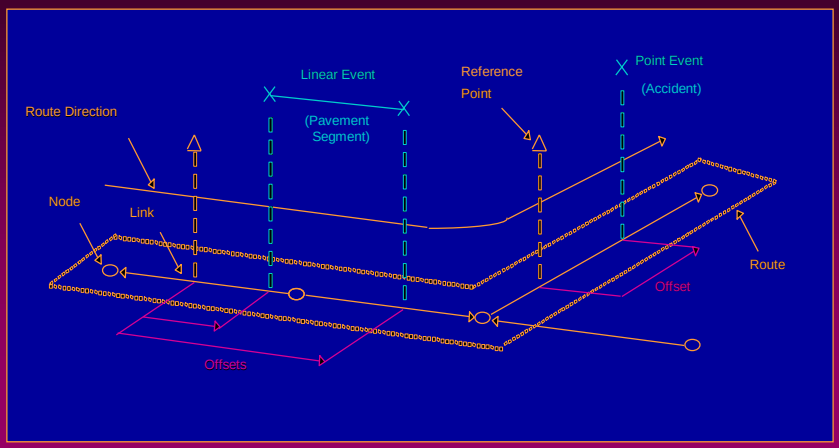
LRS Conceptual Data Model

Linear Referencing Method & Business Data



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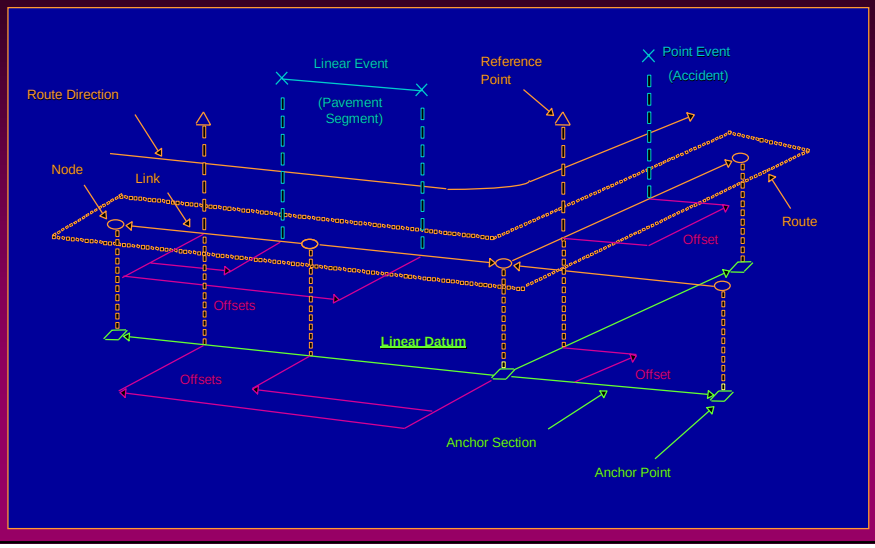
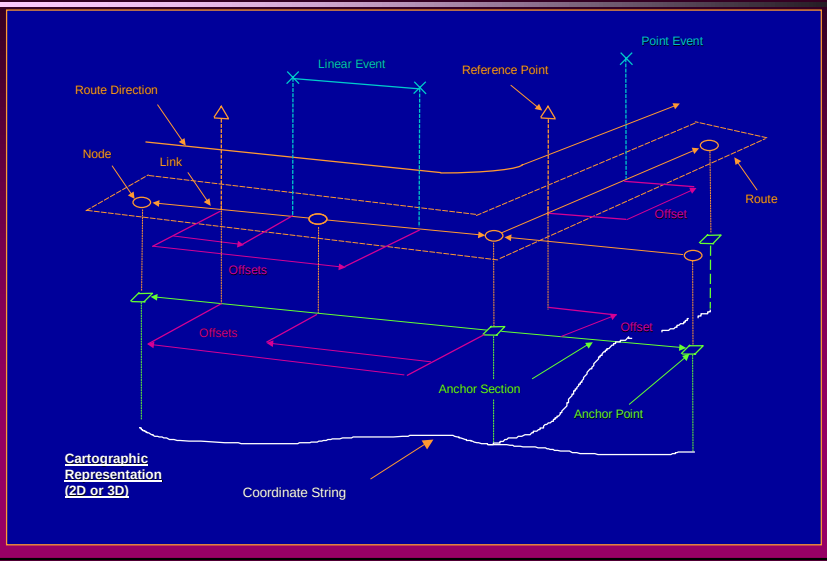
LRS Conceptual Data Model

LRM, Business Data, and Linear Datum

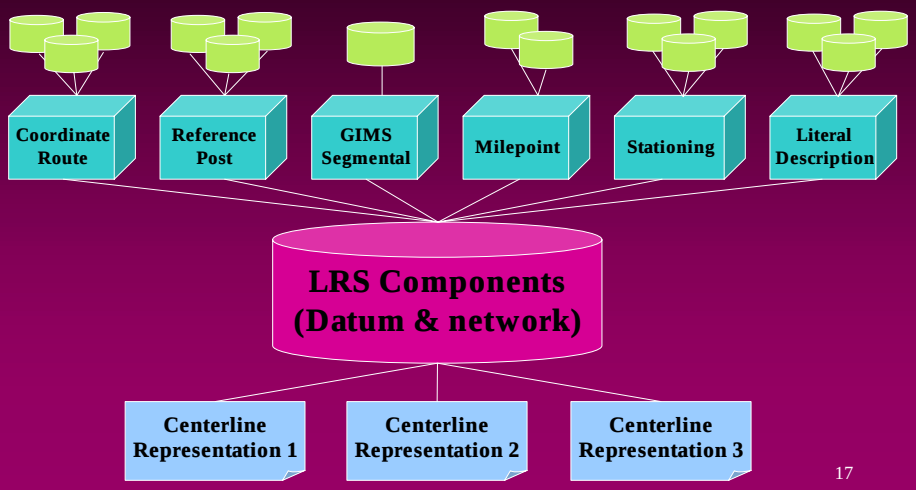


LRS Conceptual Data Model

LRM, Business Data, Linear Datum, & Cartographic Representation



LRS Operational Design
Conceptual Architectural Model



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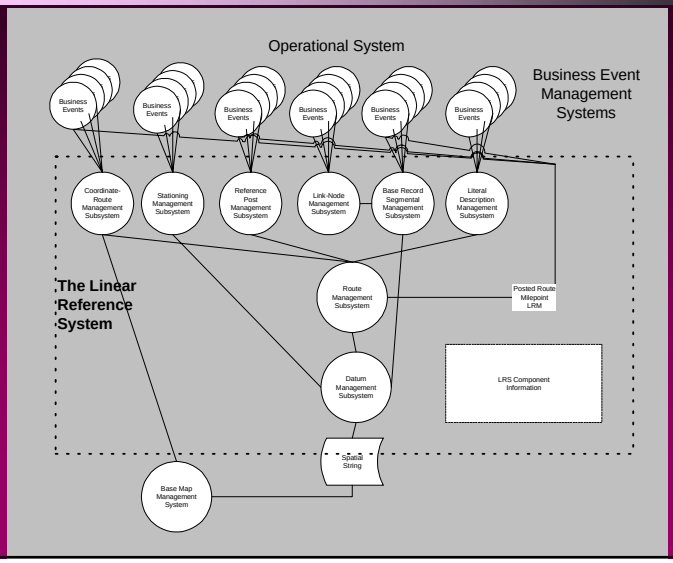
LRS Operational Design
Logical Architectural Model



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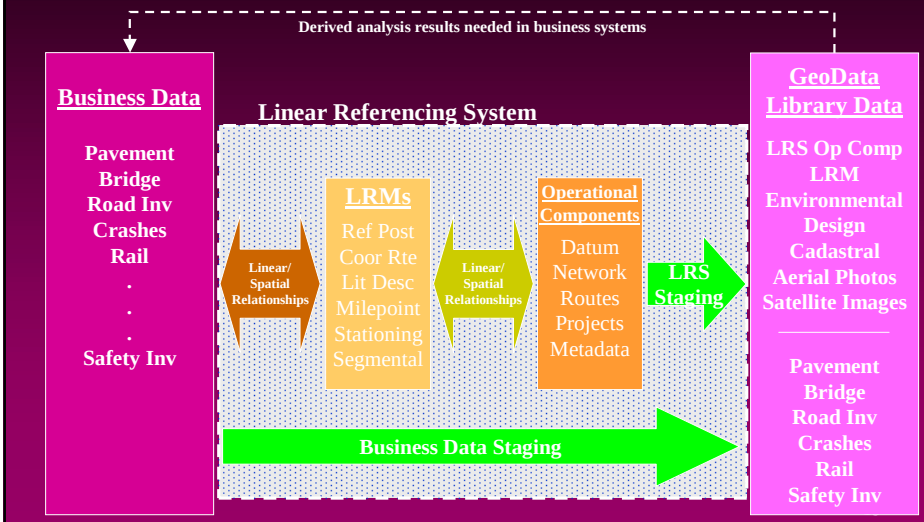
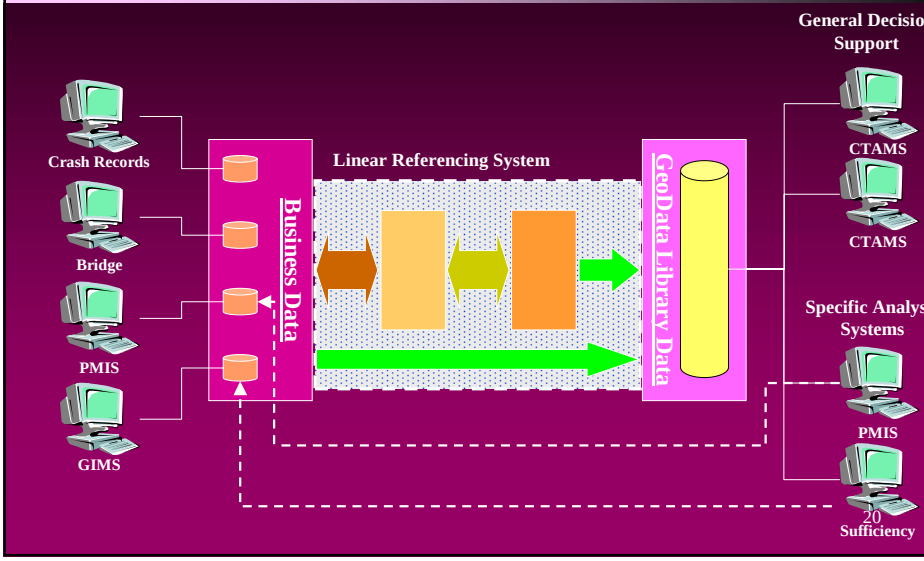
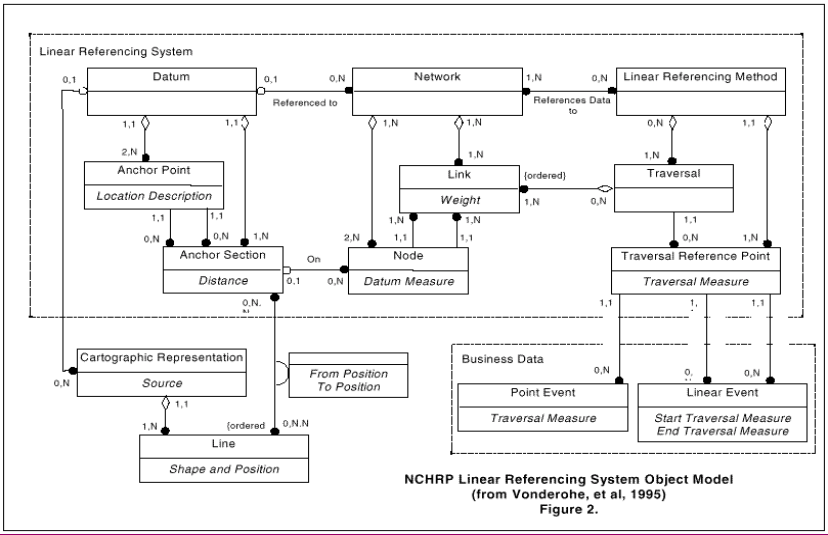
LRS Decision Support Design
Conceptual Architectural Model



LRS Decision Support Design
Conceptual Architectural Model



Linear Referencing Systems
NCHRP 20-27(2) - Object Model



NCHRP Linear Referencing System Object Model (from Vonderohe, et al, 1995) Figure 2.

LRS Project Approach
LRS Team Recommendations

- Improve accuracy of features referenced to road network
- Minimize redundancy in databases
- Minimize data maintenance
- Provide improved data integration & access
- Include all public roads

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LRS Project Approach
LRS Team Recommendations

- Establish a Linear Datum based upon the NCHRP 20-27(2) model
- Evaluate its effectiveness in a pilot study
- Move from a static base record to one that is updated in real time

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LRS Project Approach
Project Phases

- LRS Needs Assessment (August 99)
- LRS Design
- LRS Pilot Plan
- LRS Pilot
- LRS Design Revisions
- LRS Implementation Strategy & Benefits
- Project 2 Cost Estimate

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LRS Project Approach
Design Phase Subtasks

- Conceptual - To understand/obtain consensus on key system elements, resolve issues from assessment, and determine final scope
- Logical - To capture the business requirements; focusing on the what, but not the how
- Physical - To determine how to best implement requirements in the targeted technologies (GeoMedia, Oracle, etc)

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LRS Project Approach
Pilot Phase

- To test the design prior to implementing statewide. The pilot should focus on:
- Phase focus:
  - » Field data collection processes
  - » Key system elements construction
  - » Key system elements testing (benchmark results)

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LRS Project Approach
Redesign Phase

- To determine the solutions to key issues or problems with the LRS design discovered during the pilot
- Phase focus:
  - » Key system issues inventoried
  - » Best alternatives determined
  - » Impacts to design and implementation assessed

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Datum Field Measurement Decisions

Bill Schuman and Steve Kadolph

Iowa DOT

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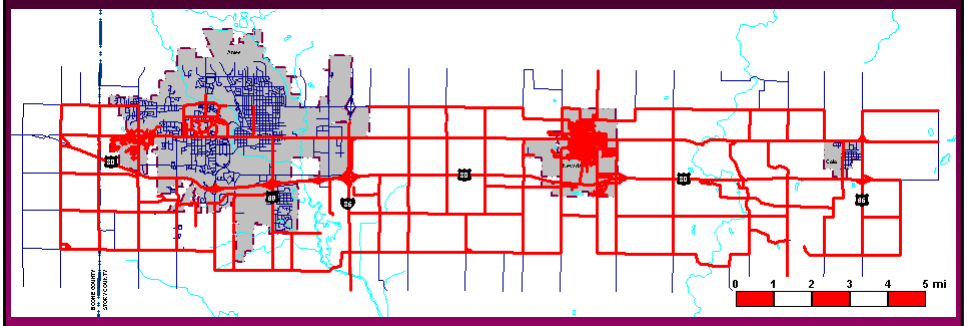
LRS Pilot Area

Story and Boone County



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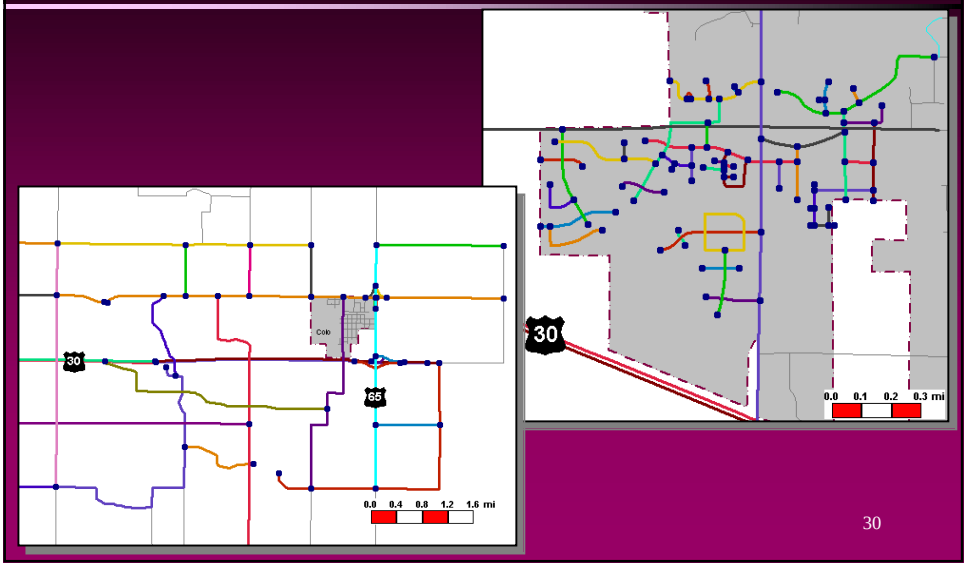
Anchor Point and Anchor Section Configuration



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Datum Measurement Methods

Anchor Point	Anchor Section
RTK GPS	DMI video van
Differential GPS	GPS video van
Aerial ortho photos	Aerial ortho photos
Project plans	Project plans
	Cartography
	Inventory data

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Anchor Points - Accuracy

- Absolute accuracy - the allowable error in longitude, latitude, and elevation on the reference ellipsoid.
- Absolute accuracy of known points, specifically anchor points, must be one meter or less.

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Anchor Point
Measurement Options

- Data collected in the field for Pilot
  - » Real time kinematic GPS
  - » Differentially corrected GPS
- Other methods used
  - » Story county aerial orthos
  - » Nevada subdivision plats
  - » Primary project plans

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Points Measured in the Field
Real Time Kinematic

- Anchor Points (103)
- Mile Posts (35)
- Bridges (10)
- Stations (32 - 16 each direction)

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Anchor Point Types

- Intersections
- Bridges/Railroads
- Dead ends
- Cul de sac
- Ramps
  - » Gore points
  - » Taper points

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Anchor Section - Accuracy

- Relative accuracy - allowable error in linear distance measurements between an anchor point and a reference point on the same anchor section
- Relative accuracy of 10 meters or less should be achieved.

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Anchor Section
Measurement Options

- Data collected in the field for Pilot
  - » Distance measuring device
  - » Differentially corrected GPS
- Other methods used
  - » Story county aerial orthophotos
  - » Primary project plans
  - » Cartography
  - » Inventory data

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Objects Measured in the Field
Video Log (GPS & DM)

- Anchor Sections (252)
- Spans (8)
- Stations (32)
- Mile Posts (35)
- Bridges (9)

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Observations
Field Measurement Problems

- Dead ends are sometime inaccessible
- Frequently it is impossible to stop
- Milepost data gathering time consuming
- Good cartographic products are necessary
- Ramps require field scouting

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Accuracy vs. Cost

- Compare methods
- Look at scope
- Choose one or more methods to implement

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Measurement Selection

- Accuracy was the driving factor
  - » Hypothesis formulated
  - » Data gathered
  - » Statistical tests performed
- Cost and its impact on accuracy
- Choose methods to implement

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Datum Creation

Methods Selected

- No one method met all requirements
- Redundant measurements required
- Orthophotos (AS & AP)
  - » Use best orthophotos available
  - » USGS DOQQs (accuracy relaxed)
- DMI/DGPS (AS)
  - » Required for ramps
  - » Missing data

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Datum Maintenance

Methods Selected

- Primary System
  - » Design Plans
  - » DMI/DGPS
- City and County Roads
  - » Plans - Work with local agencies
  - » DMI/DGPS - Inventory process

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Future

Measurement Options

- Real Time Kinematic
  - » Anchor Points
  - » Reference posts
  - » Reference features (bridges xings)
- Municipal and County Roads
  - » Focus on Arterials and collectors
  - » Reduced accuracy on local roads
  - » Work with local governments

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Organizational Decisions

- Collection to be done external
  - » Fill a LRS Manager position
  - » Staff involved in collection process
- Maintenance to be done internal
  - » Temporary increase in staff
  - » Better equipment
    - –DMI and DGPS
    - –Software needed for data collection

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Tools Required

- Visualization tools
  - » Required to create/modify datum objects
  - » Ensure process is complete
- Software to perform adjustment process
  - » Average measurements for accuracy
  - » Quality control
- Mission planning tools
  - » Required for efficient operation

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Database Model

Tom Ries
GeoAnalytics, Inc.

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Key Database Requirements

- Datum/Carto/Network
- Routes for Linear Reference Systems
- Temporal Handling
- Multiple Linear Reference Methods

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Datum / Carto / Network
Requirements

- Keep Datum/Carto/Network distinct
- Datum: most stable rep of roadway
- Datum: quantify accuracy
- Carto: support spatial analysis (GIS)
- Network: LRM foundation
- Network: routing fundamentals

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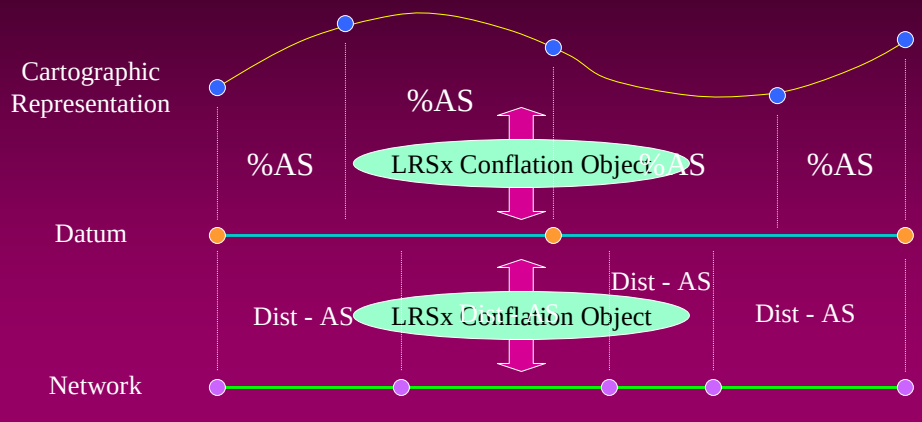
Datum / Carto / Network
Feature Association



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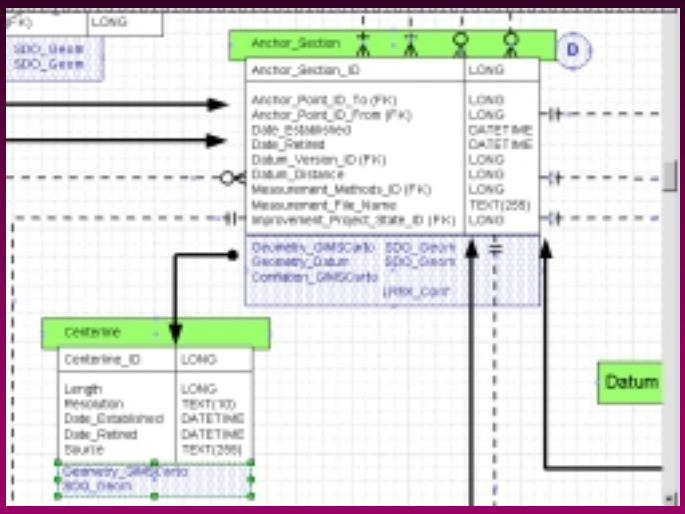
Datum / Carto / Network

Datum and Carto Association



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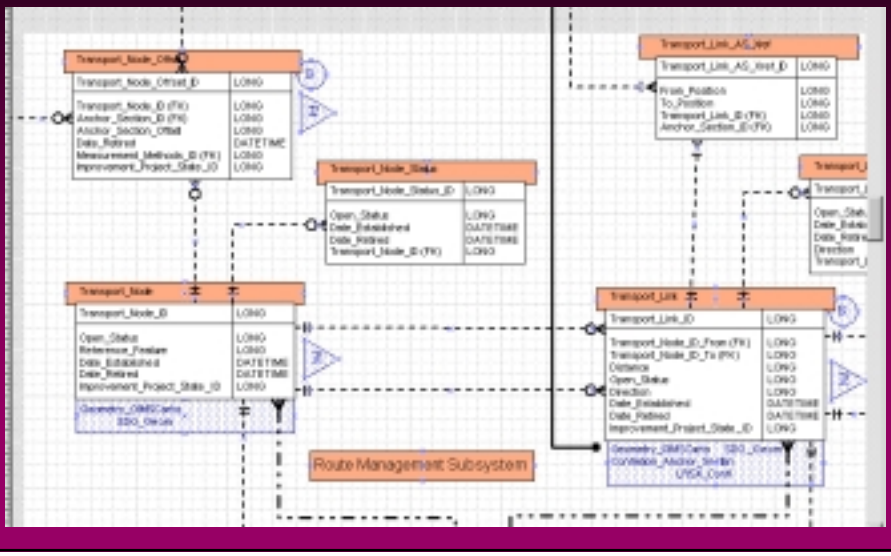
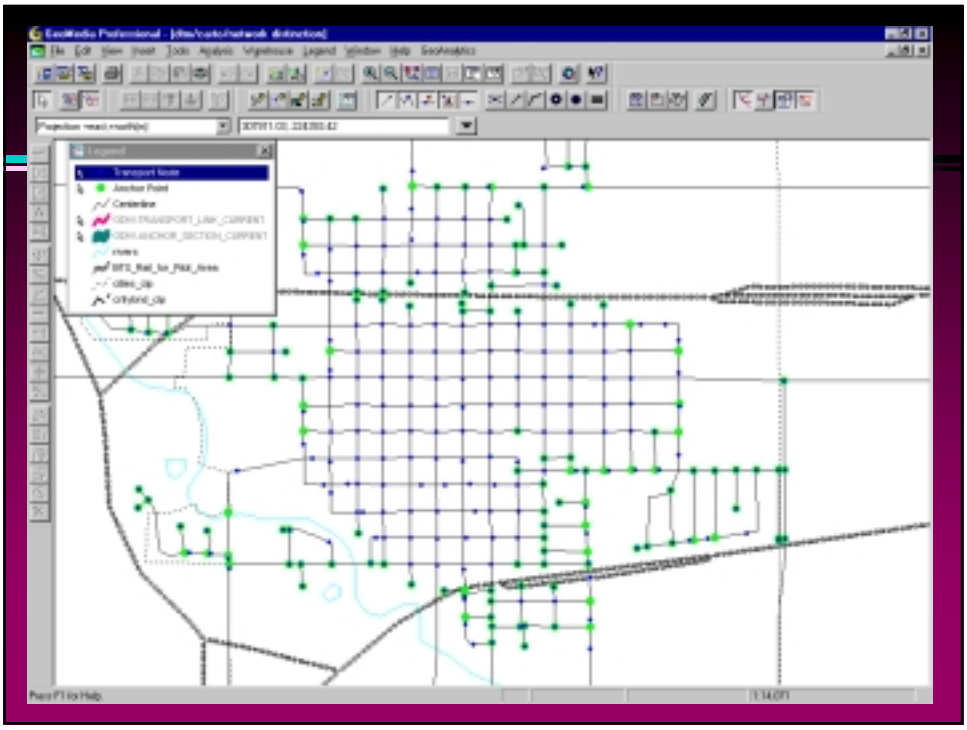
Datum / Carto / Network

Datum and Network Association





Datum / Carto / Network

- Linear/Linear Registration and Calibration Approach
- Conflation Management
  - » GIS Editing Tools for Real World Distance Editing
  - » Node Handling Part of Edit/Dyn Seg Process
- Networking Applications
  - » Network Data Independent of Geometry Condition

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Key Database Requirements

- Datum/Carto/Network
- Routes for Linear Reference Systems
- Temporal Handling
- Multiple Linear Reference Methods

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Route Requirements

- All Posted Route Systems
- Unique Route Names
- *Ramp Naming*
- *Route Aliases*
- *Concurrency Handling*
- *Detour Handling*

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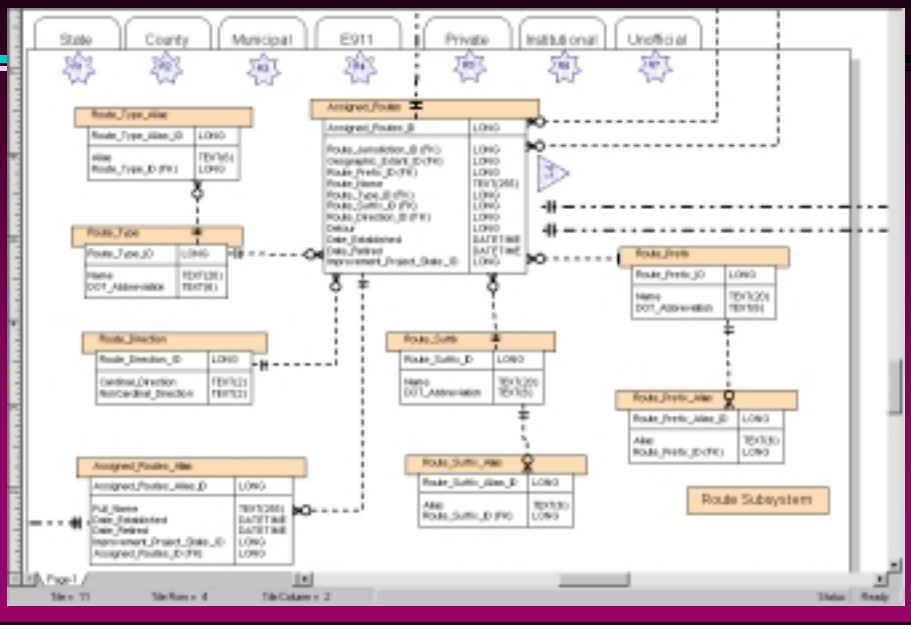
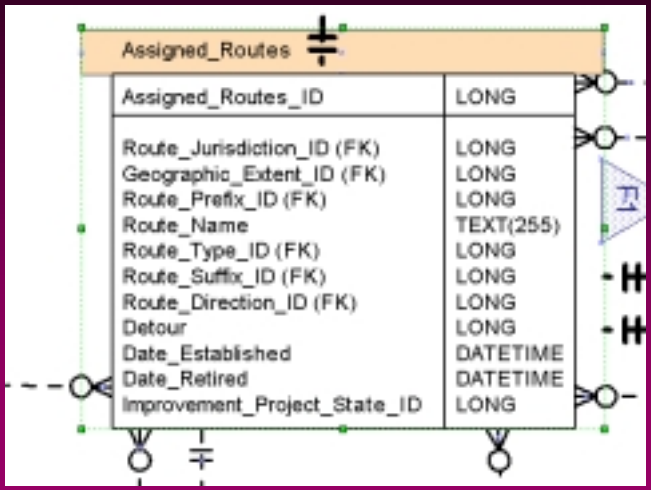
Route Requirements - *Route Systems*



Route Requirements

Unique Route Names - Decomposition



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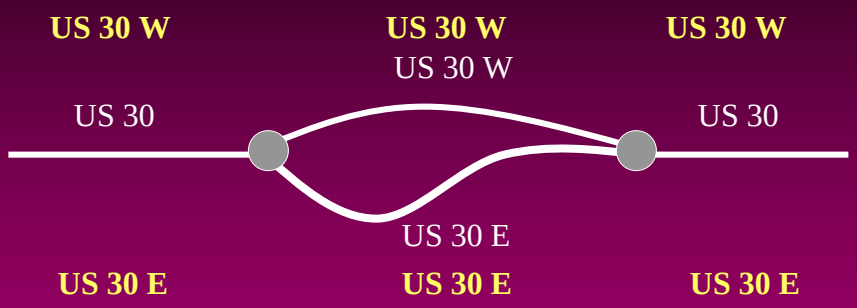
Route Requirements

Unique Route Names – Opposite Directions



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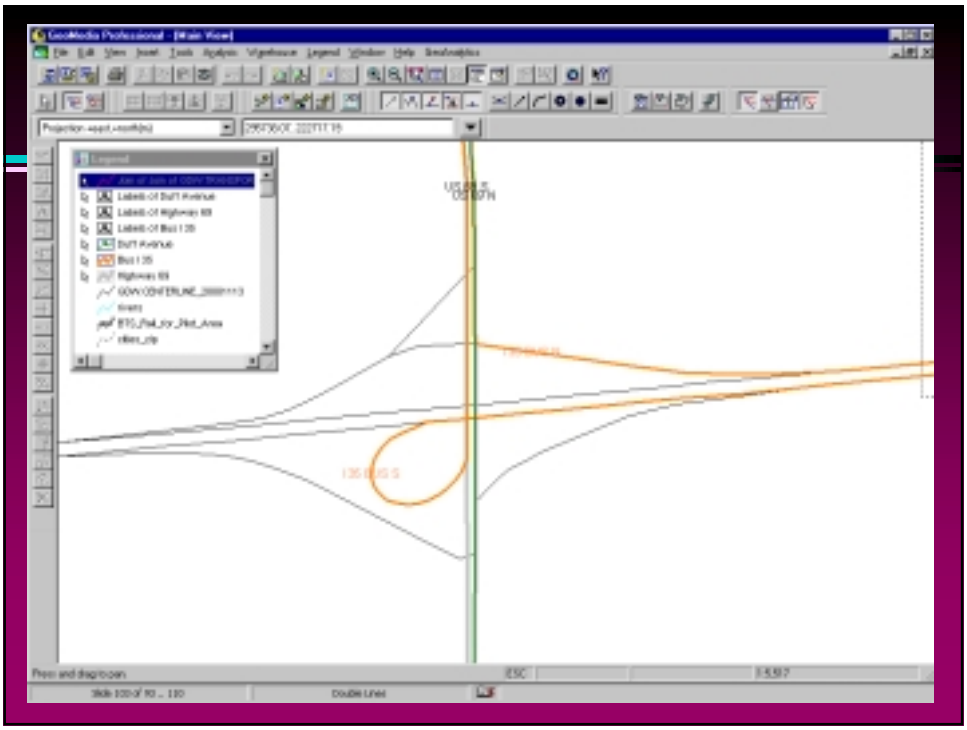
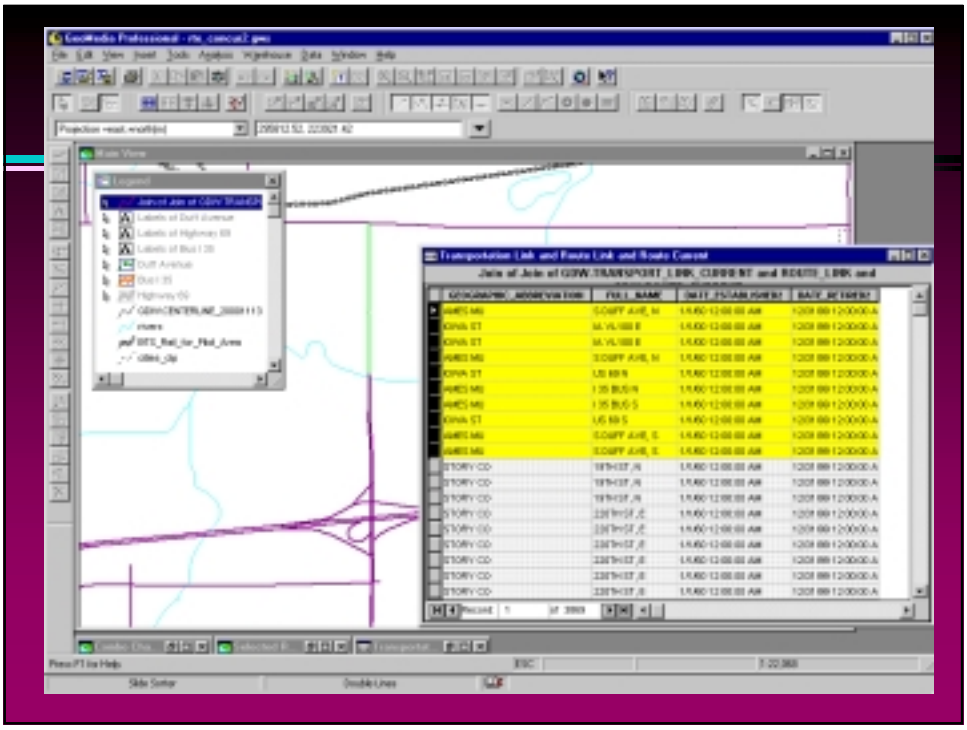
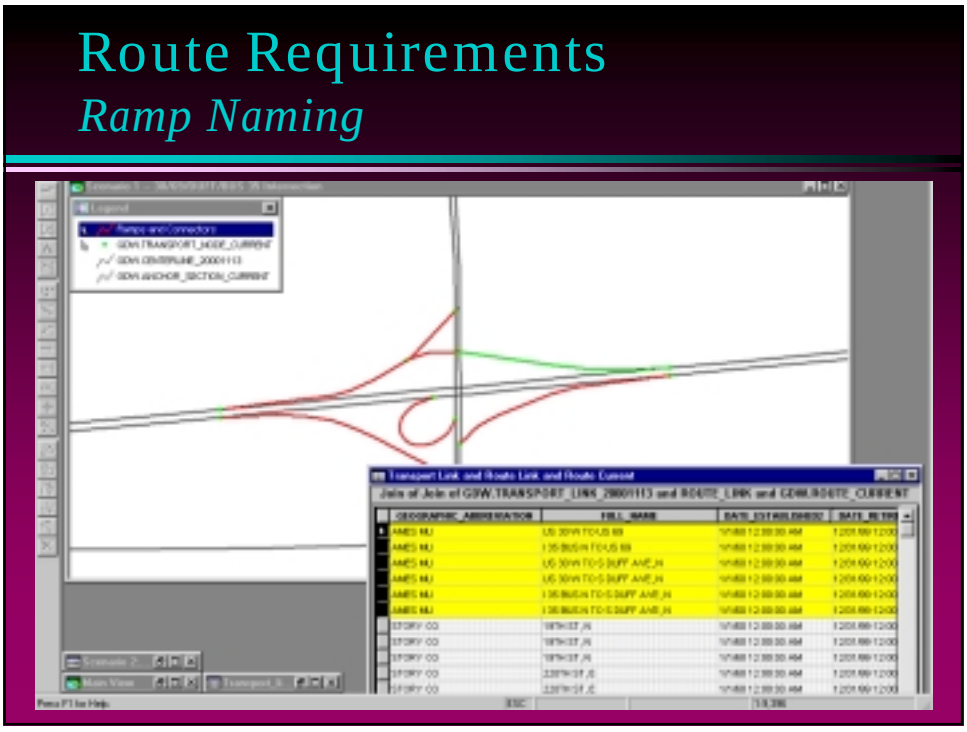


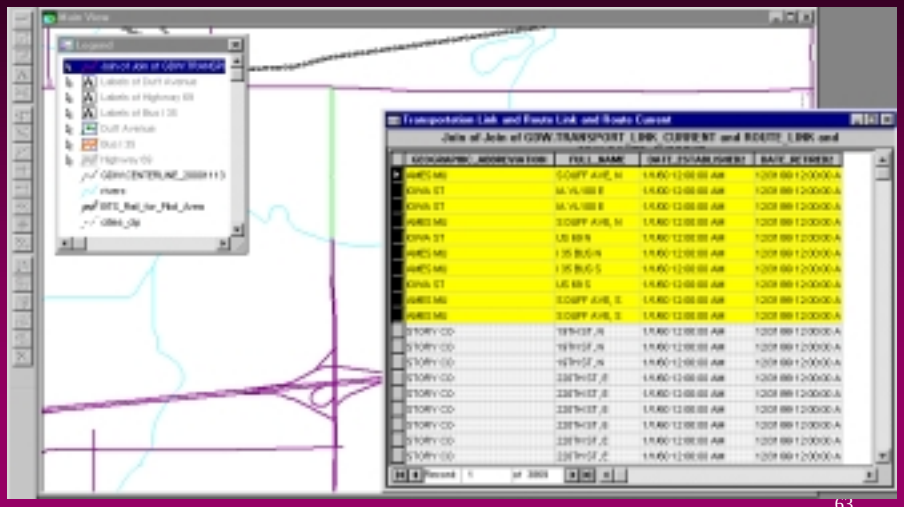


Route Requirements

Ramp Naming



Route Requirements
Concurrencies



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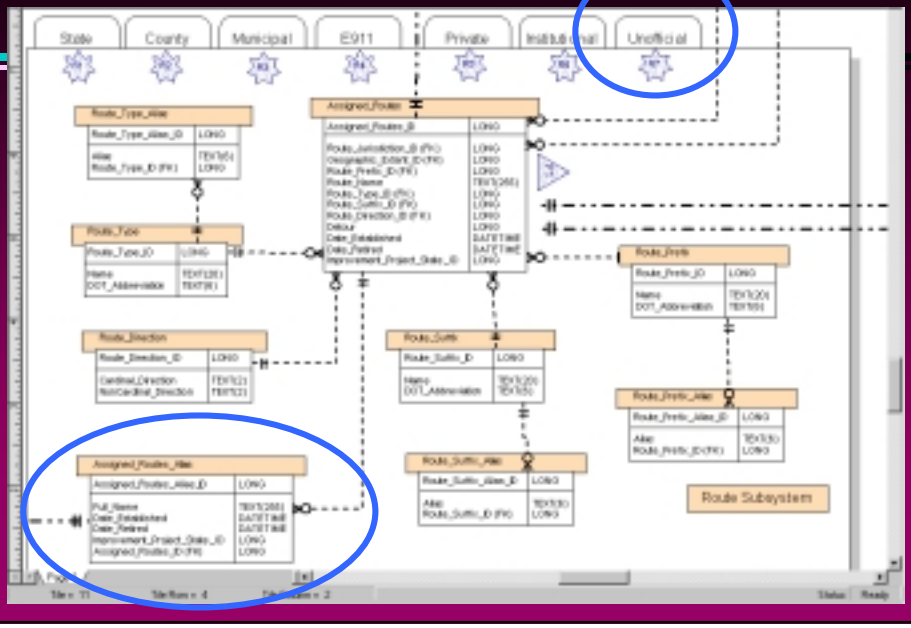
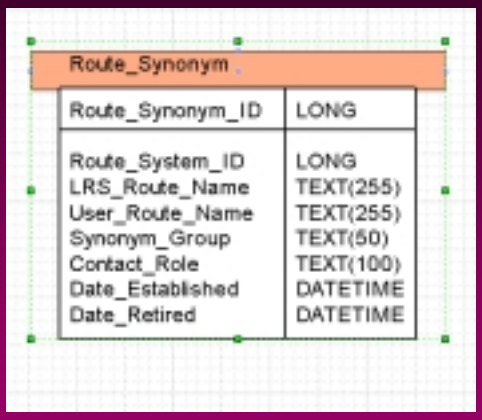
Route Requirements - *Route Aliases*



Route Requirements

Concurrencies > Route Alias Synonym



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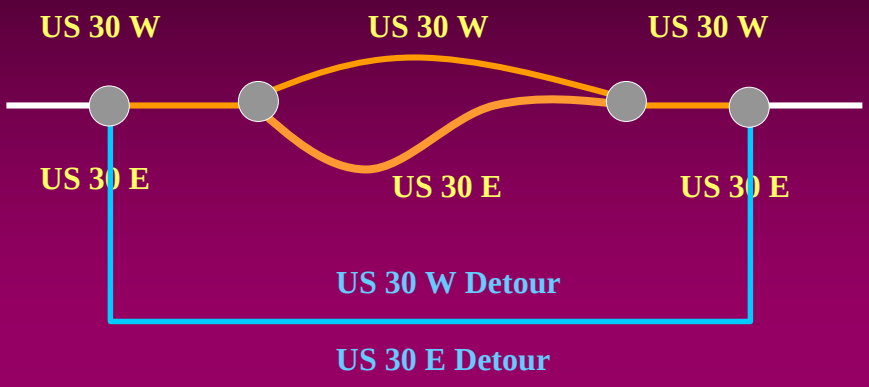
Route Requirements

Detours



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Key Database Requirements

- Datum/Carto/Network
- Routes for Linear Reference Systems
- Temporal Handling
- Multiple Linear Reference Methods

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Temporal Requirements

- Historic and Proposed Representation
- *Event tracking*
- *Feature tracking*

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Temporal Requirements
Historic and Proposed Representations

- Real World Dates
  - » *Date Established, Date Retired*
- Database Dates
  - » *Date Established, Date Retired*
- States
  - » *Strategic, Planning, Design, As-built*
- State Categories (Derived)
  - » *Proposed, Current, Retired*

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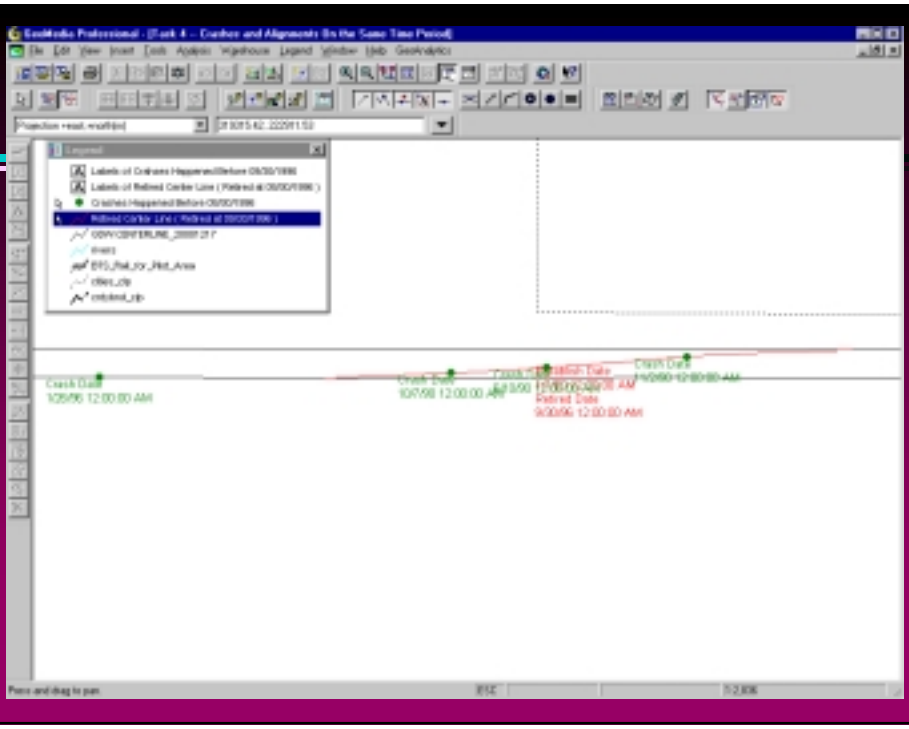

Temporal Requirements
Event Tracking

- Real World Changes
  - » Alignment, Non-alignment (routes)
- Database Changes
  - » Extension (out of state), Enhancement (improved measurement), Error (wrong measurement)
- Reason Detail
  - » Project, Feature Category, and Specific Feature Levels

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Temporal Requirements
Feature Tracking

- Specific Linear Location
  - » Anchor Section Associations
- Other Feature Associations
  - » Improvement Project Level
  - » Feature Level

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Key Database Requirements

- Datum/Carto/Network
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Location Reference Methods
Initial Official DOT "Linear" LRMs

- Reference Post (was called milepost)
- Literal Description
  - » Cross-street (derived)
  - » Reference Feature (bridge, rail crossing)
- Coordinate Route (process)
  - » Primary Format: Route, X*begin*, Y*begin*, X*end*, Y*end*
- Segmental (control section)
- Milepoint (accumulative, derived)
- Stationing (improvement project plans)

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Location Reference Methods
Literal Description (LD) Output

Comments	*LD Output Results*
Only one of several required OUTPUT formats for LD	LD{ON {10TH ST, N} AT {C AVE, W} TOWARD {D AVE, W}, 0.000 FOR 167.258}
Offset value - fuzzy tolerance needs	LD{ON {15TH ST, N} AT {IA VL100 E} TOWARD {M AVE, E}, 1.156 FOR 115.208}
On/at at same route	LD{ON {16TH ST, N} AT {16TH ST, S} TOWARD {H AVE, E}, 0.000 FOR 284.178}
Ramp names included	LD{ON {19TH ST, N} AT {19TH ST, N TO US 30 W} TOWARD {W 4TH ST, S}, 27.958 FOR 374.286}
Use of non-posted routes	LD{ON {IA VL100 E} AT {I 35 BUS N} TOWARD {I 35 BUS N}, 334.936 FOR 334.936}
Different business data with same on/at/towards	LD{ON {IA VL100 E} AT {I 35 BUS N} TOWARD {US 69 S}, 15.053 FOR 30.126}
	LD{ON {IA VL100 E} AT {I 35 BUS N} TOWARD {US 69 S}, 165.477 FOR 100.282}

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Other LRS Database Features

- Network Status
- Nested Networks
- Ramp Decomposition
- Datum Real World Locations
- Transport Systems

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Physical Technical Environment

Julian Ray
TransDecision, Inc.

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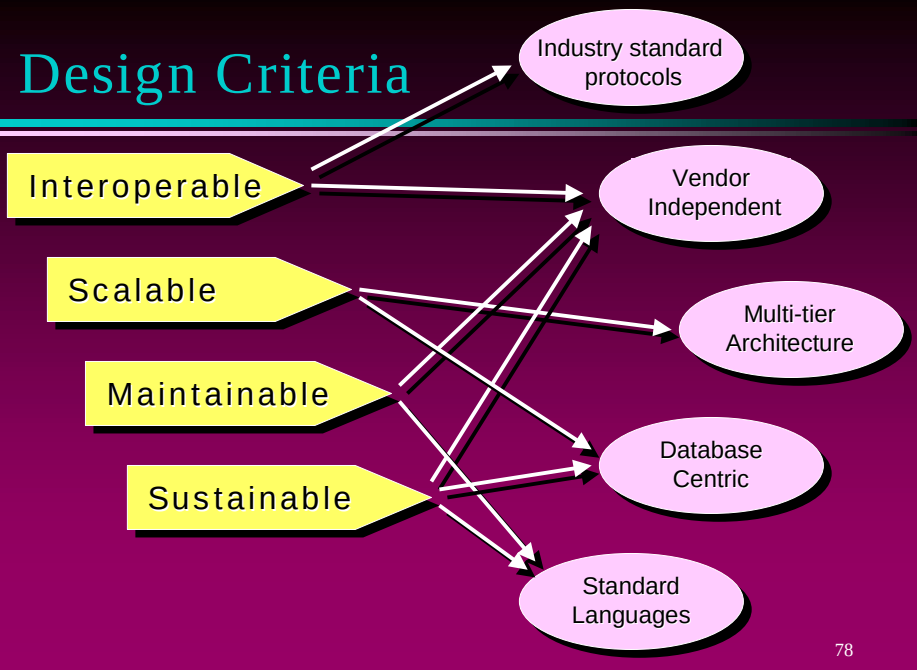
Design Criteria



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Design Issues

- Institutional
  - » Compatibility with GeoMedia Clients
  - » DOT's Information Systems strategy
- Engineering
  - » Legacy clients
  - » Structured Data
  - » Web-Enabling

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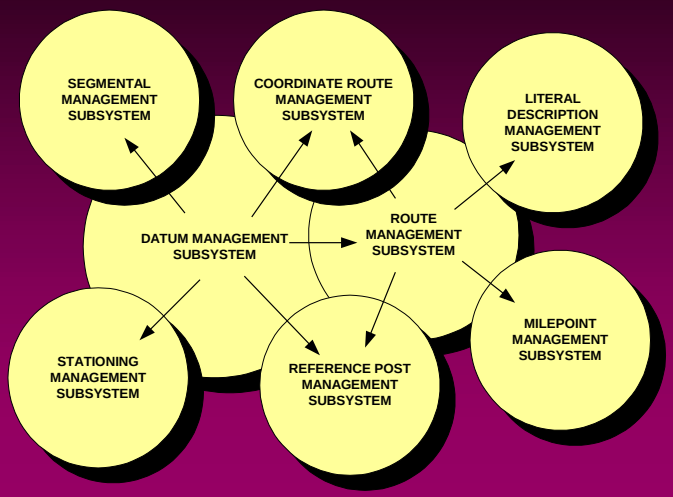
Subsystem Interoperability



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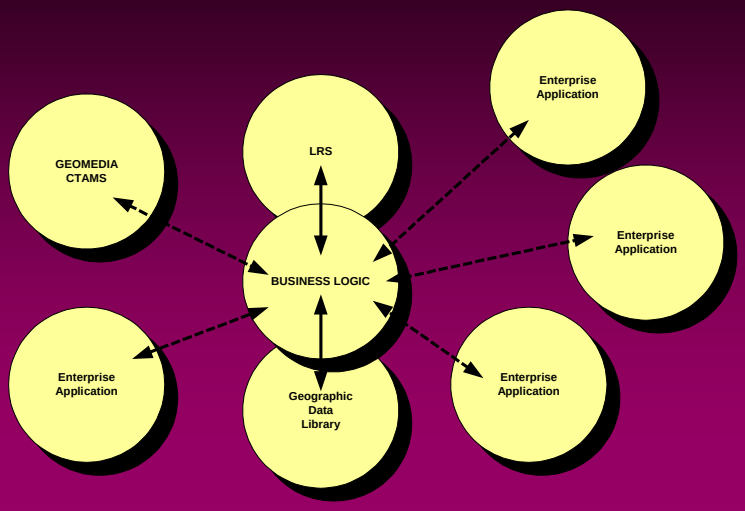
Application Interoperability



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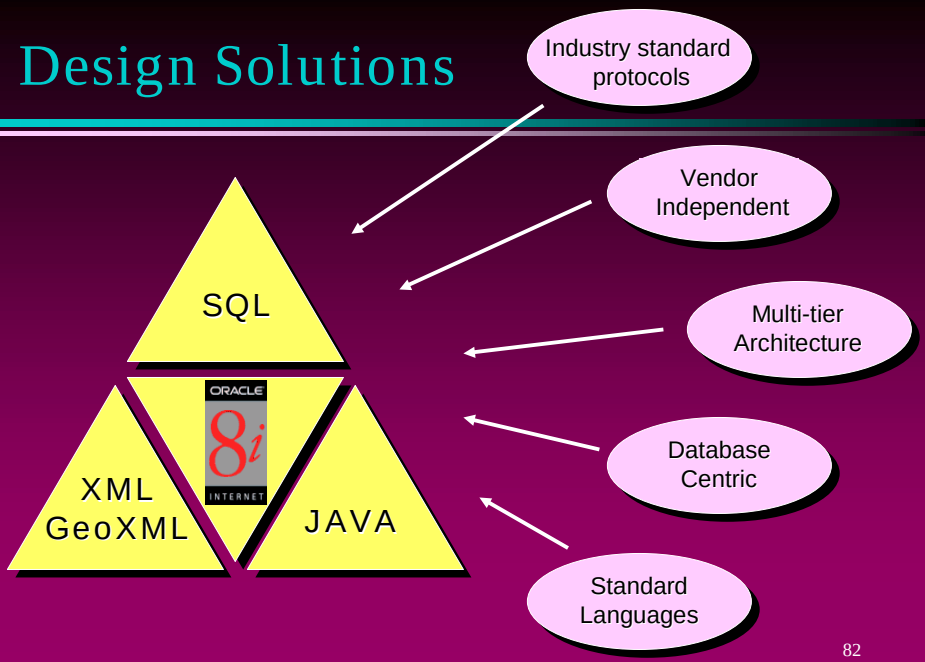
Design Solutions



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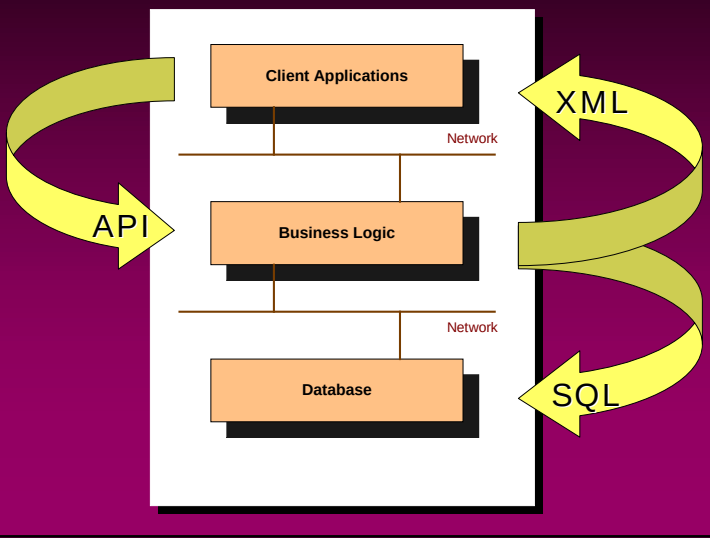
Conceptual Architecture



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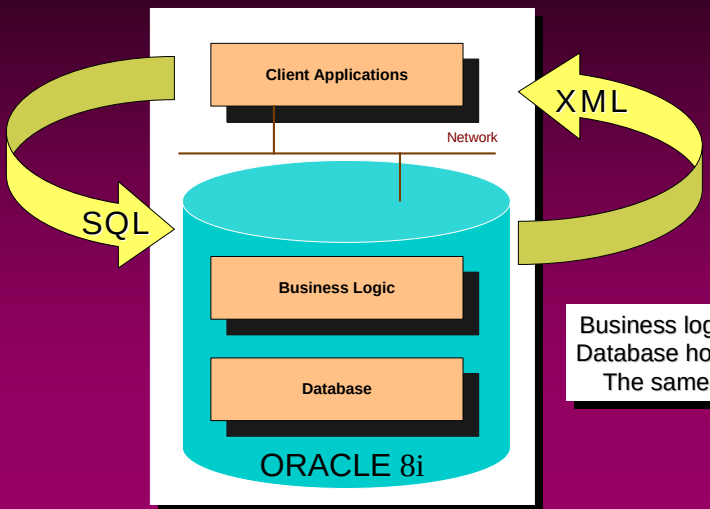
Implementation Architecture



Business logic and Database hosted in The same tier.

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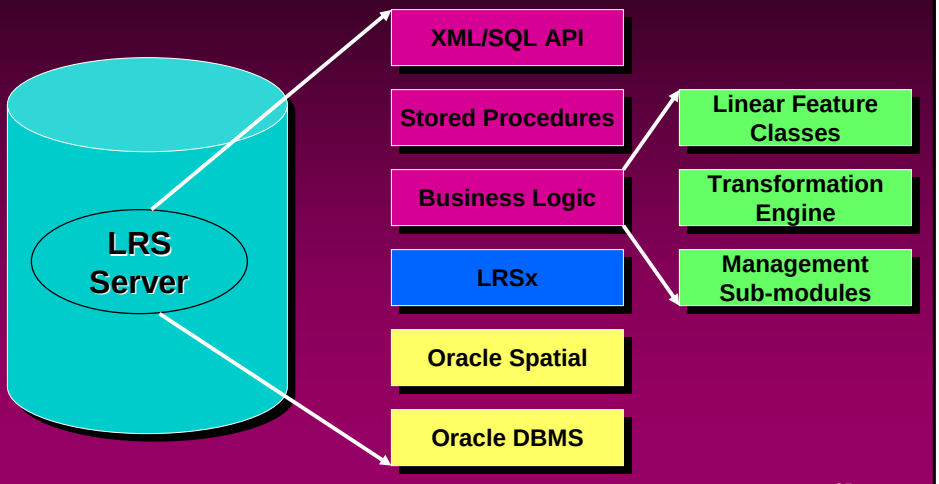
Opening the Box



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Issues to Overcome

- Managing Structured Data
  - » How LRM instance information will be passed between client and server
- Managing Structured Requests
  - » How LRS clients will request transform or overlay operations and present LRM instances

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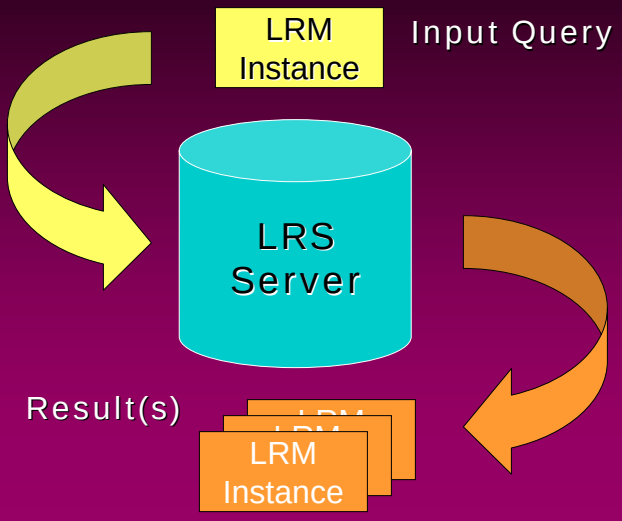
Managing Structured Data



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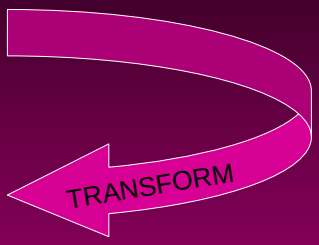
Structured Data Example

RP Route XYZ, From Post 123 + 0.25mi, To Post 125 – 0.50mi, 4/10/2001

AS 1234, FROM 500.00m TO 1250.00m
AS 5678, FROM 0.00m TO 650.00m
AS 9101, FROM 3456.00m TO 3245m



Issues for Storage, API Parameters, Interoperability

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Location Reference Instance Types

- LRM Types
  - » Milepoint, Reference Post, Datum, Stationing, Segmental, Coordinate Route, Literal Description, Geometry
- Extent Types
  - » Point and Linear
- Collections
  - » Unordered and Sequenced

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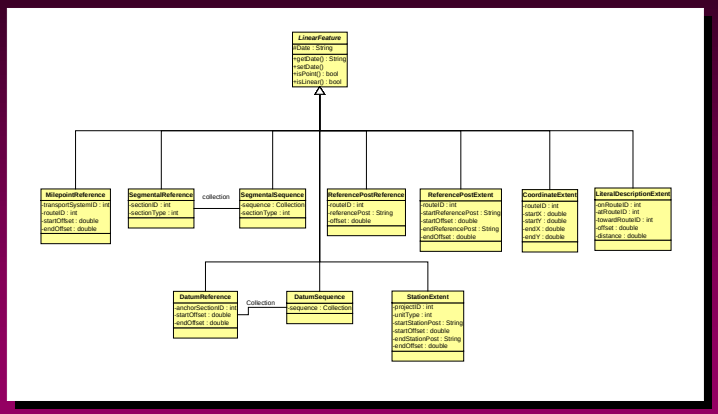
Linear Feature Class Design



XML DTD reflects Linear Feature class model

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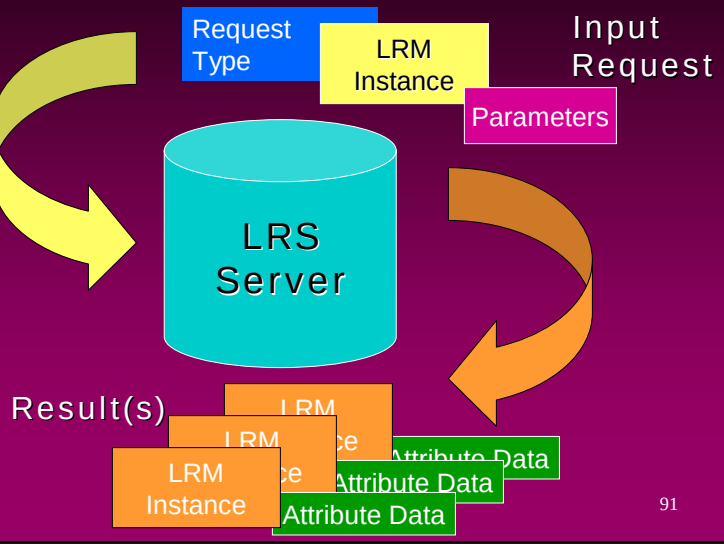
Managing Structured Requests



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XML Document Type Definitions

- Three XML DTDs Developed
  - » Linear Feature DTD
  - » Linear Overlay Request DTD
  - » Linear Transform Request DTD
- Uses GeoXML DTD for Geometry

Interoperable clients need only to be able to process XML which conforms to the LRS DTDs to be able to perform linear transform and overlay operations.

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Future of Iowa DOT LRS

Bill Schuman

Iowa DOT

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LRS Pilot Project Findings

- Found a practical approach to applying the NCHRP 20-27 LRS model
  - » Temporality
  - » Datum-based LRMs
- Our list of LRMs can be integrated using the 20-27 model
- Desired accuracies are achievable
- Most important – IT WILL WORK!

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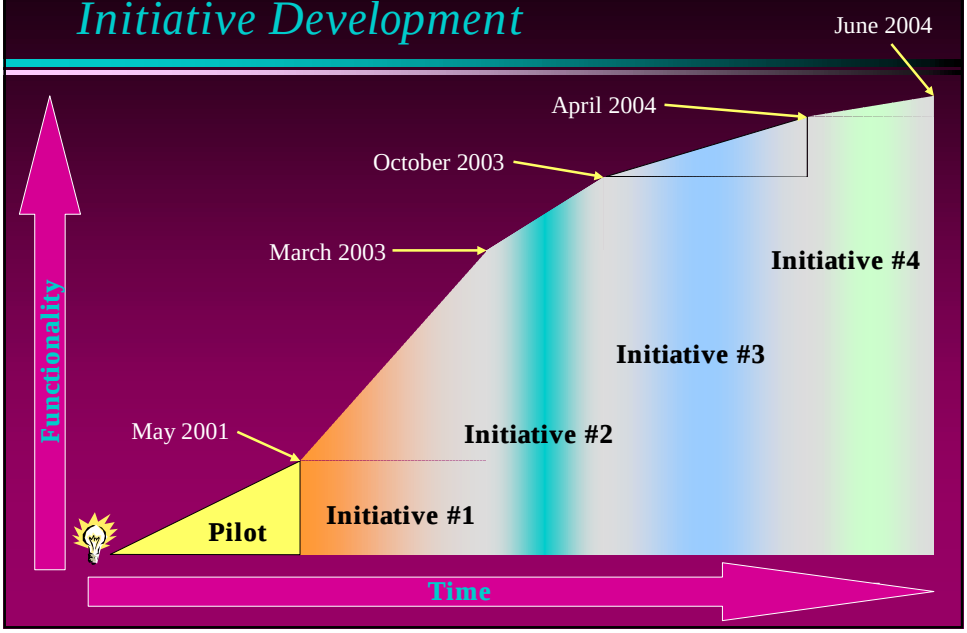
LRS Development Strategy

Initiative Development



Future LRS Development

Planned Development

- Initiative #1
  - » Finalize LRS data model
  - » Develop LRS maintenance application
  - » Design LRS datum and capture datum measurements for primary road system
  - » Deploy reference post, segmental, & coordinate/route LRMs
  - » Develop first user applications
  - » Coordinate change management

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Future LRS Development
Planned Development

- Initiative #2
  - » Enhance and finalize maintenance application
  - » Collect local roads in a region
  - » Develop milepoint and literal description LRMs
  - » Develop second level user applications
  - » Coordinate change management

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Future LRS Development
Planned Development

- Initiative #3
  - » Collect all remaining local roads
  - » Design/develop other LRMs (address ranges?)
  - » Support user application development
  - » Coordinate change management

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Future LRS Development
Planned Development

- Initiative #4
  - » Develop stationing LRM
  - » Support user application development
  - » Coordinate change management

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Questions

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